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OCCURRENCE OF ERRORS, SUGGESTIONS FOR IMPROVEMENT IN CALCULATION OF TURNAROUND TIME FOR CHINESE RAILWAYS

Ku Ting

[Comment: This article is one of a number that have appeared in issues of this periodical, dealing with the same or a closely related subject. For convenience in reading, the following glossary of terms and abbreviations is included

Glossary of Terms and Abbreviations Pertaining to Turnaround Time

Turnaround Period (TRP)

This is the elapsed time of one cycle of operations from the hour of dispatch of a loaded car until it is dispatched a second time, the first load having been unloaded and the car reloaded.

Turnaround Distance (TRD)

The distance traversed in one turnaround period.

Turnaround Time (TRT)

This is virtually the average of the turnaround periods of all the cars in operation in any unit of time such as a day, a month, or a year, or of geographical extent such as station, subbureau, bureau, a whole railroad line, a section of the country, or the country as a whole. It is the invariable practice to express turnaround time in terms of days and decimals thereof, regardless of how the duration of the component elements of the turnaround period may have been recorded.

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Number of Cars Loaded (NCLd)

Number of Loaded Cars (NLdC)

Number of Cars Unloaded (NCUN)

Number of Unloaded Cars (NUNC)

Daily Work Load (DWL)

The number of loaded cars handled on any particular day. This consists of the number of cars loaded in the home "area," plus the number of loaded cars that enter the home "area" from another "area."

(Unless otherwise indicated, the word "area," with quotation marks, will be used to indicate the home territory of the subbureau concerned.)

DWL = NCLd + NLdC entering from another area.

Loaded-Car Kilometrage (LCK)

Distance traveled by loaded cars, in kilometers.

Empty-Car Kilometrage (ECK)

Distance traveled by empty cars, in kilometers.

Empty-Car Kilometrage Percentage (ECK%)

The ratio between the empty-car kilometrage and the loaded-car kilometrage. $ECK\% = \dfrac{ECK}{LCK}$

Total Car Kilometrage (TCK)

$TCK = LCK + ECK$, or $TCK = (1 + ECK\%) \times LCK$. Data concerning LCK and ECK gathered for an extended period show little change in ratio for any particular time or area; but it may be revised when deemed advisable. Hence, when this ratio has been determined for a designated period and area, ECK% is frequently used with LCK, as above, to find TCK without having to compute ECK each time.

Total Train Kilometrage (TTrainK)

Travel Time (TrvT)

This is the elapsed time during which a train is traveling, including incidental delays at way stations for water, fuel, or lubrication, but excluding time spent in stations where switching, loading, or unloading operations take place. (If incidental stops a' way stations are excluded, that time is counted during which the train is in motion; the term used is running time:

Travel Speed (TrvSp)

Travel speed is equal to the train kilometrage, divided by the travel time.

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Average Switching Distance (ASwD)

For a fuller explanation, [ ] The term has no relation whatever to the distance covered by cars when being shunted around in switching stations or marshaling yards. Rather, it is a conceptual figure found by dividing the total car kilometrage by the total number of cars switched.

$$ASwD = \frac{TCK}{TNCSwd}$$

Total Number of Cars Switched (TNCSwd)

This refers to cars that actually underwent switching at a switching station, probably a junction point, or at least a station where the train was broken up and rearranged. Not every car that arrives at or passes through a switching station is actually switched. The proper way to record data on the number of cars switched is discussed in [ ]

Switching Time (SwT)

The time spent in switching stations when switching operations actually take place, i.e., when a train is rearranged. It includes the whole time from arrival at to departure from the switching station [ ]

Total Switching Time (TSwT)

Average Switching Time (ASwT) $ASwT = \frac{TSwT}{TNCSwd}$.

Stopping Time (StT)

The stopping time is the interval occupied by loading and unloading operations, construed to mean the whole time, from arrival to departure, that cars spend in a station where they are loaded or unloaded [ ]

Total Stopping Time (TStT)

Average Stopping Time (AStT) $AStT = \frac{TStT}{NCLd + NCUN}$

Work Rate (WR)

This term expresses the ratio between the number of cars loaded, plus the number of cars unloaded, divided by the number of loaded cars handled.

$$WR = \frac{NCLd + NCUN}{DWL}$$

Number of Cars Present (NCP)

Cars present means the cars that are physically present in the "area" at 1800 hours on any day. The number of cars present is ascertained by a mere spot tally, regardless of how long each car has been in the "area."

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Number of Cars in Operation (NCO)

The number of cars in operation is a computed figure. To obtain it, the cars in the "area" are weighted in proportion to the time which each car was in operation within the "area." The number of cars in operation is obtained by finding the total number of car-hours of the cars in the "area" in the course of the day and dividing that figure by 24 to obtain the number of car-days. The number of car-days for one day is the same as the number of cars in operation for that day.

Car-Count Formula

This is the simple formula for calculating turnaround time; it is merely the statement of the ratio between the number of cars in operation and the number of loaded cars handled. $TRT = \dfrac{NCO}{DWL}$

Time-Count Formula

This is the more complicated formula used for calculating turnaround time; it depends on the time element in recorded data of car movements. In brief, turnaround time is equal to the sum of the travel time, the switching time, and the stopping time. $TRT = TrvT + SwT + StT$.

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Problem of Errors in Calculations by the Time-Count Method

The calculation of turnaround time is closely tied to the factor of daily work load. The division of control of territory under the railway administration, bureaus, or subbureaus, varies with the railways, and the car-turnaround circumstances within or between the respective divisions and time periods involved are correspondingly diverse. What particularly complicates matters is the fact that the disposition of cars within their respective turnaround periods is so diverse and variable. For instance a car loaded in area A may be sent to be unloaded in area B, or pass through area B for unloading in area C, and perhaps it will then be sent empty to area D for reloading; and the reloading of a car may occur one, two, or more days after it was loaded.

In view of these complex circumstances, it is found necessary to be specific with respect to operating areas and time periods involved. In this article, it is to be understood that a railroad day consists of 24 hours, beginning at 1800 hours of one day and ending at 1800 hours of the next calendar day. Observing these conditions, records are kept in each territorial unit concerning the work accomplished each day, together with the time of the various work operations. From this information, the total elapsed time in hours from the beginning to the end of a full turnaround period for each car, and then for all the cars, is to be ascertained. This latter figure is to be divided by the number of cars in the daily work load. The number of hours thus derived is to be divided by 24 to convert it into days and decimals thereof, and the result will be the value of the technical term average car turnaround time for the particular area and date concerned. In other words, this is the number of days required to complete the turnaround use of the cars in the daily work load. It is a figure needed for statistical purposes and is found by methods that are rational and not open to question.

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Turnaround time may be divided into three components: travel time, switching time, and stopping time. As the distances involved in the daily work-load data vary, so also will the components that make up the total turnaround time vary. For the purpose of illustration, using a subbureau as the unit, or "area," let us see how the turnaround time is affected by changes in distances involved in daily-work-load data.

1. Travel-Time Calculations

According to the turnaround-time formula, the turnaround time is equal to the kilometrage of loaded cars times one, plus the empty-car-kilometrage percentage divided by the travel speed. Transforming some of the factors into their equivalents, the turnaround time is equal to the turnaround distance divided by the travel speed; and again, this is equivalent to a fraction whose numerator is the total car kilometrage divided by the daily work load and whose denominator is the total train kilometrage divided by the total travel time. Put in the form of equations using symbols or abbreviations, we have:

$$TRT = \frac{LCK \times (1 + ECK\%)}{TrvSp}$$

$$= \frac{TRD}{TrvSp}$$

$$= \frac{TCK \div DWL}{TTrainK \div TTrvT}$$

The count for the daily work load is reckoned from 1800 hours on one day to 1800 hours on the following day. The total car kilometrage, total train kilometrage, and total travel time are also reckoned on the same basis. The number of cars recorded as having arrived refers to the number of cars that, on a given day, have arrived at a marshaling station (understood as meaning the end of a loaded car's journey) or at a boundary station of the "area," regardless of when the train started its journey. The figures for the total kilometrage of the cars in any train that reaches a marshaling station or a boundary station before 1801 hours on a given day should be entered in the totals for that day. The same applies to train kilometrage and travel time. If a train has traveled for some time on one day but lacks a few minutes of reaching its marshaling station or border station before 1801 hours, the figures for that train must not be entered in this day's totals, but in those for the next day.

According to the above formula, if the total travel distance of the trains reaching a marshaling station or boundary station is divided by the total travel time of the same trains, the quotient will be the average travel speed. In this calculation, the probable error is very small, because the dropping off of a few kilometers of train travel distance is approximately proportional to the dropping off of a few minutes of travel time, and the result is not appreciably affected. But the erroneous increase or decrease in the figures for total car kilometrage results in a wrong increase or decrease in the duration of the total car travel time, and this is a more serious matter. Take some data from the Pai-ch'eng-tzu Subbureau as a case in point.

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The following table shows length of runs and average of up and down travel times:

Railway Lines	Track Sections	Length (km)	Time (hr, min)
P'ing-Ch'i	Ssu-p'ing--Cheng-chia-t'un	92.8	3,30
" "	Cheng-chia-t'un--T'ai-p'ing-ch'uan	111.1	3,45
" "	T'ai-p'ing-ch'uan--Pai-ch'eng-tzu	149.3	4,30
" "	Pai-ch'eng-tzu--T'ai-lai	101.6	3,00
Ch'ang-Pai	Pai-ch'eng-tzu--Ch'ien-kuo-ch'i	184.1	6,18
Pai-A	Pai-ch'eng-tzu--A-erh-shan	337.0	14,40

Assume that all these trains are running on time. As regards the trains on the sections of the P'ing-Ch'i line, whether or not a particular run is recorded, the error at most is from 3 to 4.5 hours. On the Ch'ang-Pai line one omission would involve an error of 6.3 hours; on the Pai-A line, the error would be about 14.7 hours. With the P'ing-Ch'i line running 50 cars per train, and an error in recording of 4 hours for one train, the full weight of the error would be $50 \times 4 = 200$ car-hours, converted to days, $\frac{200}{24} = 8.3$ car-days. The Pai-ch'eng-tzu Subbureau sets its daily work load at 511 cars, its turn-around time at 0.98 days, and, hence, its cars in operation at 500 car-days. The effect on turnaround time of the ~~above~~ mentioned error would be $\frac{8.3}{511} = 0.0162$ days; and in terms of percentage, $\frac{0.0162}{0.98} = 1.65$ percent. In the case of railway divisions where the traveling time is long, the error is not limited to this figure. When the territory of a subbureau is small and the number of trains operating in the territory no very many, the opportunity [for errors] to cancel each other out are few; thus, it is easy for extreme cases to occur when the error may be much greater than 1.65 percent and cannot be disregarded.

When recording train kilometrage, car kilometrage, times of train arrivals and departures, and daily-work-load data, it is imperative, for the sake of accuracy, to adhere strictly to the rule concerning the hour mark delimiting the day's operations, namely, from 1800 hours to 1800 hours. If at 1800 hours, a train has not reached its destination or a border station, and at that moment is somewhere between two stations, then the kilometrage for that train for that day must be reckoned to the last preceding station that was passed. In this way, the error would rarely ever be more than 30 minutes, (for there are few cases where two consecutive stations are so situated that the distance between them requires a running time of more than 30 minutes), and the influence of such an error would be negligible.

2. Recording Data for Stopping Time (StT)

There are three ways for recording this data:

a. Using Loading and Unloading Operations as the Criteria

Record as stopping time for the station and day when loading or unloading takes place the time for each particular car from the hour and minute of its arrival in that station until it is dispatched therefrom. This is an entirely reasonable thing to do, since cars stop only in stations where they

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are to be unloaded or loaded, or both. [Standing time at other stations in transit, unless for switching operations, will be reckoned as included in travel time.] But since it often occurs that unloading or loading operations may not be completed on the day they are started, and there are many cases where both unloading and loading operations take place in the same station during the same stopping period but when both are not completed on the same day, then the problem arises as to how these facts are to be recorded. Futhermore, after a train arrives at a station with cars to be unloaded, how is it to be known exactly when the unloading of the car begins and is finished, and just when the car, whether loaded or empty, is going to be dispatched? For these reasons, the total stopping time for possibly one or both operations cannot be calculated and reported on the day that the operations started, and perhaps not until several days later. The value of this kind of report depends on its promptness and regularity. If this method were adopted the reports would not be suitable for the purposes of analysis and car management, having lost their timeliness and hence much of their usefulness. Hence this method should not be adopted.

b. Using the Dispatching of the Cars as the Criterion

Here, the recording of the stopping time is entered in the records of the day on which the car is dispatched, and it must include the full time from the hour of arrival until the hour of dispatch. This is the method that is now in general use.

c. Using Time as the Criterion

According to this method, enter into the record for each day the actual time spent in that station by each car on that day, regardless of what day it arrived or was dispatched.

Of these three methods, method a has already been shown to be unsuitable; consequently, only method b and method c will be further examined to point out their advantages and defects and their influence on the turnaround time.

In reckoning the stopping time according to method b, when a car arrives at a station, and after loading or unloading operations, it is dispatched the same day, the time spent in that station is entered in the records for that day. But when a car is not dispatched on the day of arrival, the stopping time on day of arrival, together with that of any intervening days, is combined with that of the day of dispatch and entered in the records of the day of dispatch. The figure thus entered for a particular car is exactly the total accumulated time spent by that car in that particular station. By averaging these figures for all the cars dispatched on that day from that station, we obtain the average stopping time for that day and station. This method is comparatively convenient for the purposes of examining and comparing the lengths of time consumed for loading and unloading operations at various stations and for kinds of cargo.

However, when calculating turnaround time, what is wanted is not the cumulative time spent in the various stations for loading and unloading operations by all the cars dispatched on each day and the average of these figures; rather, to match with the daily work load which appears as a factor in the turnaround-time formula, what is wanted is the computed figure that shows the average time spent each day for loading and unloading operations by all the cars in all the stations in the "area." Method c completely meets this want.

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At this point, the effect on turnaround time of using method b should be pointed out. According to it, the time spent in a given station for loading or unloading operations of cars not dispatched on the day of arrival is not recorded on that day, hence, the aggregate stopping-time figure is not given. The effect of this sometimes may be quite important. For instance, the Cheng-chia-t'un station, on a certain day in the latter part of May [1951], had over 20 freight cars that could not be dispatched because the consignee had not yet unloaded them. Because of this, the stopping time reported for that day was smaller by several hundred car-hours than if unloading operations had been prompt and expeditious. The effect of such delays is more serious when the delay in the dispatching of cars amounts to several days, in which case the accumulated stopping time is all reported on one day, the day of dispatch. Thus on 25 May, the Cheng-chia-t'un station dispatched 56 cars having a total accumulated stopping time of 2,447.2 hours, or an average of 43.7 hours per car. Since the subbureau as a whole dispatched on that day only 138 cars, the average stopping time for the "area" was raised from the normal figure of 8.4 hours to 22.9 hours.

On 14 May [presumably also at Cheng-chia-t'un], there were dispatched 31.5 [sic] cars for which there was recorded an average stopping-time of 43.8 hours; on 17 May, 15 cars were dispatched with an average stopping time of 85 hours. At another station, Ta-shih-chai, on 28 April, one car had a stopping time of 88.5 hours. During the first quarter of the year, the Ch'uan-kou station had a car that, on dispatch, had stopped for more than 170 hours, or more than 7 days, which cumulative total was all reported on one day. The effect of this was to increase the turnaround time of the whole "area" for that particular day. A further point to be noted in this connection is that the turnaround time for this bureau, when computed by the car-count formula, does not agree with the figure when computed by the time-count formula. [For explanation of car-count formula and time-count formula, see OO-W-27704.]

Let us see what is revealed by examining the data cited for 25 May at Cheng-chia-t'un, and let the figures speak for themselves. Suppose that all of the 56 cars dispatched on that date had had an average stopping time on that date of 24 hours. In that case, the aggregate stopping time reported would have been less than that actually reported by 46 car-days: $56 \times (43.7 - 24) = 56 \times 19.7 = 1103.2$ hours = 46 car-days. The effect on the turnaround time for the Pai-ch'eng-tzu Subbureau would have been a reduction by $\frac{46}{511} = 0.09$ days, which is a decrease of 0.2 percent: $\frac{0.09}{0.98 \times 100} = 9.2$ percent. Such big discrepancies as this are not negligible and must not be permitted to occur.

From such data as these, it is plain that, for the sake of accuracy in calculating turnaround time, the data for stopping-time should be reckoned by method c. But method c also has its deficiencies. Concerning the cars dispatched on a certain day from a certain station, just how long each car stopped and what the average stopping time was is information that could not be ascertained from the station reports if prepared according to method c. Which of the above-mentioned methods is the better for securing the statistical data needed to determine the average stopping time?

It is my personal opinion that the form for the statistical report on stopping time hitherto in use should be expanded to secure the good points of both methods, by recording both categories of stopping time, each one supplementing the other, thereby permitting accuracy in the calculation of turnaround time, and facilitating the investigation, analysis, and control of stopping time of freight cars. Of course, to record both sets of stopping-time figures on the same form, it will be necessary to make some changes in

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the headings of the columns. To avoid confusion, the following distinctions could be made. The stopping-time data recorded according to method b might be denoted, "Cumulative Stopping Time of Cars Dispatched This Day," or more concisely, "Cumulative Stopping Time;" data recorded according to method c might be denoted, "Actual Stopping Time of Cars Dispatched This Day," or more concisely, "Actual Stopping Time." The suggested form might be as follows:

Numerical System Car-Stopping-Time Data Sheet   Date.............

	Car number	1
	Car type	2
A.	Car Arrival	
	Month.........day..........	3
	Hour.........minutes..........	4
	Train number	5
B.	Car Dispatch	
	Month.......... day..........	6
	Hour.........minutes..........	7
	Train number	8
	Number of operations (loading, unloading, or both	9
C.	Cumulative Stopping Time (car-hours)	
	From arrival to dispatch	10
	From arrival to the beginning of work	11
	In station	12
	On special tracks	13
	From end of working period to dispatch	14
	Actual stopping time (car-hours on this particular day)	15
	Stopping time of through cars	16
D.	Stopping Time of Non-Revenue Producing Cars	
	Hour of arrival	17
	Hour of departure	18
	Stopping time	19
	Length of demurrage (hours)	20
	Remarks	21

The proposed new form of this sheet would be the same as the old form, except for the addition of the items relating to actual stopping time.

Following is an illustration of the recording of actual and cumulative stopping-time data. Suppose that, yesterday, a car arrived at a given station at 1450 hours and was dispatched today at 0250 hours. The actual stopping time today would be a period of 8 hours and 50 minutes (reckoning from 1800 hours yesterday to 0250 hours today). The cumulative stopping time would be a period of 12 hours. Suppose a car arrived today and was dispatched today, in this case, the actual and the cumulative stopping time would be the same. Again, suppose a car that arrived today at 0540 hours but was not dispatched until tomorrow [i.e., after 1800 hours today]; in that case, no entry should be made in the cumulative column for today, and the actual stopping time for today would be 12 hours 20 minutes.

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The summaries of the above-described sheet should be sent by all stations every day to the subbureau dispatching office to supply data on which the latter may calculate the car turnaround time for the "area." Furthermore, the subbureaus report this and other information to the dispatching office of the bureau or to the railway administration. According to this method, the burden of work on the recording clerks is not appreciably increased; but the result will be more accurate and reliable data on stopping-time for use in calculating turnaround time. But there is another matter that should be point the actual stopping time for the "area" for each day will not be the same. Is the reason for this the fluctuation in actual stopping times reported by each individual station? In this matter, it must be pointed out that it is desirable to set for each station a standard car-stopping-time allowance, in order, by making comparisons, to trace the cases of excessively long stopping times to their causes. However, this standard stopping-time allowance for any particular station, used when planning takes place, and the average cumulative stopping time which is determined when cars are dispatched, are the same; for in the long run, there is actually no difference between the average car stopping time and the cumulative car stopping time. The standard stopping-time allowance is based on the time required for one work operation. This figure need not be announced to each station; it is only for the guidance of the subbureau office and for comparative analysis by the railway administration. (Consideration should be given to the fact that in an ascertainable proportion of cases, both unloading and loading operations take place in the same station, and a suitable adjustment should be made when the standard-stopping-time allowance is determined.)

Problem of Errors in Calculations by the Car-Count Formula

The car-count formula is actually a simplified form of the time-count turnaround-time formula. This fact may be demonstrated by showing how the former may be derived from the latter by successive transformations in terms of the latter. The time-count formula is:

Turnaround time (TRT) = $\frac{1}{24}$ [travel time (TrvT) + switching time (SwT) + stopping time (StT)]. (Times recorded in terms of hours.)

$$TRT = \frac{1}{24}\left[\frac{(1 + ECK\%) \times TRD}{TrvSp} + \frac{(1 + ECK\%) \times TRD}{ASwD} \times ASwT + WR \times AStT\right].$$

$$= \frac{1}{24}\left[\frac{(1 + ECK\%) \times (LCK \div DWL)}{TrvSp} + \frac{(1 + ECK\%) \times (LCK \div DWL)}{TCK \div TCSwd} \times ASwT\right.$$

$$\left. + \frac{NCLd + NCUn}{DWL} \times \frac{TStT}{NCLd + NCUn}\right]$$

$$= \frac{1}{24}\left[\frac{TCK \div DWL}{TrvSp} + \frac{TCK \div DWL}{TCK \div TCSwd} \times ASwT + \frac{TStT}{DWL}\right]$$

$$= \frac{1}{24}\left[\frac{TCK \div TrvSp}{DWL} + \frac{TCSwd \times ASwT}{DWL} + \frac{TStT}{DWL}\right]$$

$$= \frac{1}{24}\left[\frac{TTrvT}{DWL} + \frac{TSwT}{DWL} + \frac{TStT}{DWL}\right]$$

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$$= \frac{1}{24}\left[\frac{\text{Total time cars in transit}}{\text{DWL}}\right] = \frac{\text{Total time cars in transit}}{24} \times \frac{1}{\text{DWL}}$$

$$= \frac{\text{Total number of days of cars in transit (car-days)}}{\text{DWL (cars)}}$$

$$= \frac{\text{Total cars in operation (car-days)}}{\text{DWL (cars)}} = \text{TRT} = \text{car-count formula (days)}$$

In the foregoing transformations of the terms in the time-count formula, it will be noted that what is referred to as "cars in operation" is expressed in terms of car-days, since each car is considered to be in operation 24 hours a day within the "area," or what corresponds to it. It is also obvious that the results as to turnaround time derived by use of the time-count formula and by the car-count formula should be the same. When employing the car-count formula, the figure used for the number of "cars in operation" is derived from the re-corded data as to the number of cars in use in the "area" at 1800 hours of the day of record. The chief source of this data is the border stations, which re-port the number of incoming and outgoing cars during each hour throughout the day of record. The lesser source of this data is the stations that report cars within the "area" which are put in or out of commission during the day of record. To recapitulate, the required total number of cars in operation is made up of the following elements:

(A) The number of cars in operation in the "area" at 1800 hours yesterday.

(B) The number of incoming cars today.

(C) The number of outgoing cars today.

(D) The number of cars that were put back in commission today.

(E) The number of cars that were put out of commission today.

(F) The total number of cars in the "area" in operation at 1800 hours today.

Then, $A + B - C + D - E = F$

It is apparent that this figure pertains only to number of cars and does not contain any time factor. It is simply an indication of the status at a definite time. Its use is due to the fact that the number of cars in the area is constantly changing, and if no steps were taken to ascertain the facts, there would be no way of knowing what the status of the rolling stock in the area is. Still less would it be possible to devise plans for the economical utilization of the rolling stock. Current reports from all the stations in the "area" containing the elements mentioned above constitute a convenient way of knowing what the count is; and only in that manner can the rolling stock situation be controlled; suitable allocation of cars be maintained, and the tendency for an "area" to retain surplus cars be counteracted.

However, to record merely the number of cars physically present in the area at 1800 hours supplies a figure which cannot rightly represent the num-ber of cars in operation throughout the day and, hence, should not be used in the formula for the calculation of turnaround time. [In the present dis-cussion, cars present, as distinguished from cars in operation, is used to mean the number of cars present in the "area" at 1800 hours.] The manner in which the cars-present figure is arrived at does not correspond with the man-ner by which, and the scope within which, the daily-work-load figure is as-certained; hence, to use the former in calculations with the latter figure is contrary to the principles of statistics. The degree of influence on the ac-curacy of the turnaround-time calculations due to the use of the cars-present figure may be judged from the two following explanations.

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1. Errors Associated With Recording the Number of Incoming and Outgoing Cars

When reckoning the number of cars present at 1800 hours, there may be no actual difference in the number of cars that had entered by 1759 and by 1801. But in calculating turnaround time, the situation is something other than just cars present, since cars entering the "area" at 1801 may be cars in use for a whole day of 24 hours, whereas cars entering at 1759 were in the "area" only one minute on that day, which is practically equivalent to not being in operation in the "area" at all. Similarly, between cars that are recorded as having left the "area" at 1801, and those having left at 1759 hours, there may be a difference of 24 hours of operation in the area, for the latter is recorded in today's data, while the former is recorded in tomorrow's data. Consequently, when the figure for cars present is used in place of cars in operation is divided by the daily work load, the figure derived for turnaround time may be very much in error. This sort of invalid increase or decrease in the turnaround figure for a particular day creates in the operation of trains a situation that should not exist.

Every day in every "area," as the hour of 1800 approaches, great efforts are made to run departing trains through the border stations into the adjoining "areas" before the deadline to reduce the number of cars recorded as in use in the "area" (which is actually the number of cars present). And similarly, the home "area," as 1800 hours approaches, tries to create situations to prevent trains from another area from passing inward through border stations before the deadline to avoid recording an increase in the number of cars in use within the "area."

In the smaller "areas," such as are under a subbureau, the car turnaround time is usually about one day. In places where the turnaround time is a little under one day, if the number of loaded cars received from another "area" is increased by one or more cars, this not only increases the daily work load but also the number of cars in operation, and therefore the result is an increase in the turnaround time. If there are empty cars in the incoming trains, the effects are still worse, so that even greater efforts are made to find excuses for not immediately receiving the train and for delaying it until after the deadline. This is done universally. For this reason, there is created a stoppage of trains around 1800 hours, with consequent delays.

Because of the wrong practice in the use of present methods of calculating turnaround time, the discrepancies between the calculated figures are too great. This wrong practice affords incentives and opportunities for deliberately resorting to various tricks to gain selfish advantages, or it unintentionally causes differences between the results of the calculation of turnaround time by the car-count and time-count formulas. Let us use some figures to show how serious these discrepancies may be.

As an illustration, take a train drawing 50 cars, which is scheduled to pass outward through a border station at 1801 hours of the next day, but which, by special efforts, is made to pass outward today at 1759 hours. According to the car-count formula, the turnaround time would be decreased by $\frac{50}{511} = 0.098$ days. Since the normal turnaround time for this "area" is 0.98 days, the change in percentage would be $\frac{0.098}{0.98} \times 100 = 10$ percent; and the turnaround time for today for this "area" would be $0.98 - 0.098 = 0.882$ days.

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Now, for comparison, make a calculation according to the time count formula. Assume that the operating time of each car is shortened by 2 minutes (the difference between 1759 and 1801 hours); that amounts to a reduction of 50 x 2 = 100 minutes. The turnaround time is thereby reduced by

$$\left(\frac{100}{60} \times \frac{1}{24}\right) \div 511 = 0.00014 \text{ (days)},$$

which, compared with the normal turnaround figure, is a reduction to only $0.98 - 0.00014 = 0.97986$ days, a change of only $0.00014 \div 0.98 \times 100 = 0.014$ percent. The changes reckoned by the two different formulas are 0.098 and 0.00014, where the former is 700 times as great as the latter. The difference between the two reductions in turnaround time, when compared with the normal figure, in percentage, is $(0.97986 - 0.882) \div 0.98 \times 100 = 9.986$ percent.

According to these calculations, the discrepancies are much too great to be negligible. As for the subbureau that got rid of one more train today, the turnaround time figured by the car-count formula was abruptly reduced. It was possible, without any great increase in work, to record a higher degree of performance. As for the receiving subbureau, its turnaround-time for that day was suddenly increased; its day's efforts to keep the turnaround time low were canceled out by being forced at the last minute to receive another train from the other "area."

Let us try to see how these discrepancies occur. They are due entirely to the practice of using the number of cars present in the "area" at 1800 hours in place of the number of cars in operation to calculate the turnaround time. It is possible, under some circumstances, that the discrepancy might amount to as much as 24 hours, or one whole day. If accuracy is wanted, some way must be found to eliminate this source of error. Complete accuracy of calculations is possible but it is not attainable due to the limited capacity of the recorders of data. However, perfect accuracy in this matter of records is not necessary, because we can use a method which reduces the sources and magnitude of the errors. In the method of recording data for switching time, if a train enters and leaves a switching station within one hour, no car-hour time in operation is recorded; while, if the train departs one hour or more after arrival, one car-hour of operation is recorded for each car in the train. So, using this method, the "area" receiving a train of 50 cars at 1759 hours, would record an increase of only 50 car-hours of operations for that day. Again, take as an example the data of the Pai-ch'eng-tzu subbureau. Convert the 50 car-hours to days, $\frac{50}{24} = 2.08$ car-days. By the car-count method, the effect of the extra train received is to increase the turnaround time by $\frac{2.08}{511} = 0.004$ days. Compared with the normal turnaround time, this is an increase of $0.004 \div 0.98 \times 100 = 0.4$ percent.

By recording an increase of only one car-hour for each additional car, instead of 24 car-hours, the increase of car-hours has been reduced to $\frac{1}{24}$ of what it would have been under the cars-present method of recording cars in operation. By the same token, it may be said concerning the incoming train of 50 cars arriving just before 1800 hours, that the number of additional cars has been reduced to the equivalent of $\frac{50}{24} = 2.08$ cars regarded as in operation for a whole day of 24 hours.

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2. Cumulative Discrepancies in Connection With Incoming and Outgoing Cars

Since the number of cars present, by definition, only indicates the number of cars in use that remain in the "area" at 1800 hours, if the number is large, it does not follow that there has been a large number during each hour of the whole day; and if the number of cars present is small, it does not follow that there was a small number of cars in operation throughout all the hours of the day. Take another example to explain this point. (In the accompanying table, the number of cars incoming and outgoing includes those cars that have that day been put in or taken out of commission within the "area.")

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Time Record Sheet for Cars in Operation   Date................

Incoming and Outgoing Record

Time	Incoming	Outgoing	Incoming Differences	Outgoing Differences	Cumulative Total of Incoming Differences	Cumulative Total of Outgoing Differences	Cars in Area
(Number of cars present at 1800 hours yesterday)							500
1800-1900	105	92	13		13		513
1900-2000	94	105		11	2		502
2000-2100	84	96		12		10	490
2100-2200	48	51		3		13	487
2200-2300	50	47	3			10	490
2300-2400	78	83		5		15	485
2400-0100	45	78		33		48	452
0100-0200	54	60		6		54	446
0200-0300	85	48	37			17	483
0300-0400	34	80		46		63	437
0400-0500	94	83	11			52	448
0500-0600	78	92		14		66	434
0600-0700	83	56	27			39	461
0700-0800	95	86	9			30	470

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0800-0900	101	93	8			22	478
0900-1000	95	48	47		25		525
1000-1100	64	46	18		43		543
1100-1200	55	83		28	15		515
1200-1300	46	74		28		13	487
1300-1400	43	51		8		21	479
1400-1500	76	95		19		40	460
1500-1600	84	76	8			32	468
1600-1700	105	93	12			20	480
1700-1800	116	85	31		11		511
Total	1,812	1,801	224	213	109	565	11,544

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From this table, it can be seen that the number of cars present at the end of the day is 511, which is 11 more than the allotted number.

For the data on cars in operation, if we simply follow the method of the nonnumerical system that is employed in securing data on switching time, as has been done in the above table, the car situation each hour is noted on the record sheet. The figures in the last column then represent the number of car-hours of cars in operation for each respective hour. The total at the bottom of the last column signifies that on this day, there were 11,544 car-hours of cars in operation. By dividing this figure by 24, it is converted into 481 car-days.

$$11,544 \text{ (car-hours)} \div 24 \text{ (hours)} = 481 \text{ (car-days)}$$

This is 19 car-days less than the 500 car-days that the "area" had at the beginning of the day and 30 less than at the end of the day. The change in turn-around time is indicated as $\frac{30}{511} = 0.0587$ days; and $\frac{0.0587}{0.98} \times 100 = 6$ percent.

This discrepancy obviously shows that the figures for turnaround time calculated by the car-count method and the time-count method do not agree with each other. The existence and sources of the discrepancies of two kinds discussed above are attributable to the use of the cars-present figure instead of the cars-in-operation figure in calculations [of turnaround time for the "area"]. Which figure is to be accepted and which one rejected? This selection is a very easy one to make; we can positively assert that the correct figure to use is the one derived by converting into car-days the total number of car-hours of all the cars in operation in the "area" in the course of the day. Making our calculations on this basis, the turnaround time will be practically the same, whether derived by using the car-count method or the time-count method; if there is any discrepancy, it will be very small, probably under one percent.

Concerning the figure for cars in operation to be used in the turn-around time calculations, it should be derived by adding together the car-hours of cars in operation for each hour and for all the stations in the "area." In practice, it is not necessary for every station to carry out all the computations for each hour of the day. It is only necessary that each station record the hourly data indicated in columns 6 and 7 in the accompanying table so that it can report the totals at the end of the day. When these totals are summarized by the subbureau for all the stations in the "area," the number of car-days of cars in operation for the whole "area" may be computed by means of one of the following formulas:

a. Car-days of cars in operation for today equals the number of cars present at 1800 hours yesterday, plus the cumulative total of incoming differences, minus the cumulative total of outgoing differences, divided by 24.

b. Car-days of cars in operation for today equals the number of cars present at 1800 hours yesterday, minus the cumulative total of outgoing differences, minus the cumulative total of incoming differences, divided by 24. To illustrate this computation, we will use the figures we have in the above table, for one station only. In this case it will be more convenient to use formula b.

Todays's car-days of cars in operation $= 500 - (565 - 109) \div 24$

$$= 500 - 456 \div 24 = 500 - 19 = 481$$
car-days

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According to this procedure, there is no appreciable increase in work on calculations imposed on the clerks in the various stations; they will continue to record, much as at present, data concerning all car movements, hour by hour, throughout the day and send their reports promptly to the subbureau of the "area." The errors arising from the two sources discussed above may be entirely avoided. Naturally, the undesirable actions hitherto having taken place just preceding 1800 hours every day will no longer take place. The following favorable results will be realized:

a. Hereafter, neither in planning nor in operation, will it be necessary to fear the impossibility of getting rid of outgoing trains around 1800 hours and its effect on daily performance, or to fabricate false reports as to daily performance. Daily train movements can be properly planned and carried out. It will be possible to arrange for uniform density of train movements throughout the day, avoiding both congested and slack periods.

b. Hereafter, there will be no occasion for rushing outgoing trains and resisting the reception of incoming trains; hence, bottlenecks and delays around 1800 hours will not occur. Thus, the travel time of trains would be reduced and greater efficiency in train operations would be realized.

Jen-min T'ieh-tao

Editor's Note: This article covers much the same ground as was covered in an article that appeared in Volume III, No 6, June 1951, of this periodical, entitled "A Study of the Methods of Calculating Turnaround Time." To emphasize the importance of this subject, the present article is printed herewith in full, with the hope that comrades will study it and contribute their opinions as reference material for further progress in the study of this problem.

In a table on page 10, of Volume III, No 6, among the data of the total number of cars in operation, the number of surplus cars from the preceding day was included by mistake; because of this error, the number 12,154 wrongly appears. The number should be 11,633. In the text of the article, using hours as the unit, the average number of cars in operation should be 484.7 (11,633÷24); and the turnaround time should be 1.21 (484.7 ÷ 400).

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